APPENDIX 4

Attainment Modeling and Air Quality Analyses for the 1-Hour Ozone Standard

Introduction

The four Lake Michigan states of Illinois, Indiana, Michigan and Wisconsin have been pursuing the development of a regional agreement to demonstrate attainment of the 1-hour ozone standard for the last 10 years. The Lake Michigan Air Directors Consortium (LADCO) provides the platform for regional air quality assessment. Efforts have included an intensive field study on ozone formation in the region followed by several regional ozone air quality modeling and data assessment efforts since 1990. The LADCO states have entered into memorandum of understanding to pursue these regional evaluations and related control programs studies in an attempt to reach regional agreement on ozone attainment efforts.

Over the last year, LADCO has modeled a series of regional control strategies to define the control level necessary to demonstrate attainment by 2007. Those efforts include emission controls for VOC and NOx from upwind states. This provides a basis for assessing the additional NOx (and/or VOC) control effort needed regionally, in the three states of Illinois, Indiana and Wisconsin, to meet a US-EPA "test" for modeled attainment in a Lake Michigan receptor area.

Notable control elements in the baseline for all the attainment modeling include:

- the most recent federally-adopted new vehicle and equipment emission standards,
- the 1996 and 1999 ROP reductions and RACT measures for VOC for all areas in the modeling domain,
- Stage 2 vapor recovery, enhanced I/M and other CAA regulations like reformulated gasoline applied to the appropriate Lake Michigan areas,
- the impact on heavy duty diesel truck NOx emissions associated with the 1998 engine manufacturer consent decrees,
- Clean Air Act mandated controls including the Title 4 Acid Rain NOx reductions.

Current Status

With the recent federal Appellate Court decision reinstating the NOx SIP Call for Michigan, Illinois and Indiana, but not Wisconsin, the most recent modeling effort has been structured consistent with the Court's decision. The modeled attainment demonstration strategies reflect a NOx SIP level of reduction for IL, IN and MI and a lessor effort on the part of WI.

Due to the uncertainty created by the Court's decision on the NOx SIP Call, the LADCO states could not reach agreement on the scope of follow-up attainment modeling. Therefore, DNR completed a modeling assessment to support this attainment demonstration assuming the application of the NOx SIP Call in every state except Wisconsin. Those modeling results are discussed below.

Ozone Modeling Summary

LADCO uses a system of three models to evaluate the effects of various ozone control strategies on the Lake Michigan region. The meteorological model provides detailed estimates of meteorological variables such as wind fields, temperature, solar radiation and humidity for use in the chemistry model. The emissions model has the capability to adjust emissions for time of day and day of week, distribute emissions to the appropriate geographic areas and separate emissions into various chemical species for processing in the chemistry modeling. Using the output from the emissions and the meteorological model, the chemistry model simulates the transport and formation of ozone in the region. The resultant predicted ozone concentrations are used to determine if acceptable air quality is achieved under a given control strategy. DNR uses LADCO's modeling system and baseline information to test the effectiveness of various control programs that are of interest to us.

LADCO developed baseline inventories for the ozone episodes and used the emissions model to forecast 2007 baseline conditions. Control assumptions under assessment for the various reduction strategies were applied to the projected inventory baselines for the 2007 attainment tests. For the largest NOx sources in the region, LADCO utilized average daily ozone season NOx emissions assembled from 1995/96 ozone season monitoring data reported to EPA under the Acid Rain program. For sources and source categories without this continuous emissions monitor (CEM) data, LADCO applied economic growth forecasts to adjust daily estimates from data reported for 1996 under the states' annual inventory structures. For mobile sources, LADCO applied EPA's MOBILE model and applied adjustment factors to account for more recent regulations and technical modeling assumptions. Off-road engine and area source emissions were similarly grown and controlled in as consistent a fashion as could be applied by the four states.

LADCO conducted most of the modeling using a 12 Km grid structure. LADCO found that the finer 4 Km grid structure for the model did not improve model performance and greatly increased model run time. The current LADCO evaluations use four ozone episodes, two from the 1991 and two from 1995. The four episodes reflect ozone problems in slightly different parts of the Lake Michigan domain. Two of the four adequately reflect "typical" ozone episodes in Wisconsin.

Meeting US EPA's Attainment Test

The 1996 EPA guidance for demonstrating 1-hr ozone attainment describes two acceptable approaches. The most difficult approach involves passing a deterministic test that requires a demonstration for all modeled days of predicted maximum ozone concentrations below 125 ppb, the 1-hour ozone *[monitoring]* standard. A second approach involves statistical tests for passing three benchmarks more reflective of the form of the standard. The statistical test incorporates an adjustment to reflect how severe the meteorology was during the modeled episode. If neither approach clearly demonstrates attainment, a "weight-of-evidence" determination may be conducted. The "weight-of-evidence" provides additional information to those reviewing the attainment demonstration to determine if attainment is probable in the real world even though the tests do not show attainment of the standard.

Attainment can be demonstrated with either approach as long as the modeling platform accurately predicts ozone under the tested conditions. Separate performance statistics are derived in the analysis to determine if projected peak concentrations are close enough and if there is any overall bias in the modeled output.

Modeling results show that implementation of NOx controls incorporated in this rule package are not sufficient in and of themselves to demonstrate attainment of the standard. These "local" NOx control programs include ROP requirements for 2002, 2005 and 2007 plus some additional VOC and NOx control in the primary and secondary ozone control regions. For the 1-hour ozone standard to be attained in Wisconsin, these local NOx control programs have to be augmented by implementation of the NOx SIP call in Illinois, Indiana and the other upwind states subject to the SIP call.

8-Hour Average Ozone Concentrations Resulting from Implementation of the 1-Hour Attainment Plan

Although implementation of the ozone control programs identified in the plan, in conjunction with sufficient upwind reductions, will achieve attainment of the 1-hour ozone standard, they fall short of demonstrating attainment for the 8-hour standard. The modeling results show that emission levels that meet the 1-hour standard result in 8-hour ozone concentrations that exceed the 8-hour standard in eastern Wisconsin. Additionally, ozone concentrations exceed the 8-hour standard in western Michigan, where Wisconsin sources significantly contribute to the high concentrations. Therefore, if the 8-hour standard is eventually upheld in federal Court, additional NOx and/or VOC reductions will be necessary in the Lake Michigan Region.

Contribution of Ozone Precursor Emissions from the Secondary Ozone Control Region on Ozone Concentrations in Eastern Wisconsin

To determine the spatial extent and magnitude of the impact of the NOx emissions in the Secondary Ozone Control Region, on ozone levels in the Lake Michigan area, DNR conducted additional modeling in May, 2000 that consisted of "zeroing out" the NOx emissions in the Secondary Ozone Control Region. “Zeroing out" these emissions and comparing the predicted ozone levels with those predicted when these emissions are occurring provides a good "signal" concerning the spatial impact of these emissions, and the magnitude of that impact. DNR staff did modeling for two ozone episodes, July 13-21, 1991 and July 7-18, 1995. These modeling runs used meteorological conditions from 1991 and 1995 in conjunction with baseline emission levels projected for 2007, consistent with the LADCO modeling approach.

There are several items to note concerning the preparation of the emissions files for the "zero out" scenario. First, all NOx emissions were set equal to zero including biogenic NOx. These emissions are very small compared to anthropogenic NOx emissions. Second, the boundary of the Secondary Ozone Control Region is quite irregular. The area was approximated using 12 km wide grid cells.

After the modeling was completed, plots were generated showing the differences in peak 1-hour concentrations between the two base cases, (July 1991 and July 1995) and the zero-out runs. Results from the July 13-21, 1991 episode indicate ozone concentration decreases ranging from 14 ppb to 37 ppb. This means that under the conditions being modeled NOx emissions from stationary, area and mobile sources in the Secondary Ozone Control Region contribute from 14 to 37 ppb of the ozone in downwind areas. The geographic orientation of the ozone plume attributed to these emissions varies with the meteorological conditions occurring on a particular day. The maximum concentration decreases in the ozone nonattainment area are on the order of 20 ppb. For the majority of high ozone days during this episode, the affected area runs from Oshkosh, through the Fox Valley to Green Bay, then northeastward to Door County.

Results for the July 7-18, 1995 zero-out run show ozone decreases from 9 to 26 ppb. Again, this means NOx emissions in the Secondary Ozone Control Region are associated with ozone concentrations ranging from 9 to 26 ppb in downwind areas. Because this episode is of longer duration than the July 1991 episode more meteorological conditions were modeled. The results show the ozone plume affecting a wider area, from northern Illinois and Indiana, to central Michigan, and to the Fox Valley and Door County. Although magnitudes of the differences are less for this episode, the wind direction and speeds were higher, resulting in impacts as far away as central Michigan.

What these zero-out runs demonstrate is that NOx emissions in the Secondary Ozone Control Region contribute to elevated ozone levels in the nonattainment counties and that 1-to-1 offsets and performance standards for new sources are reasonable measures for assuring attainment and maintenance of the 1-hour ozone standard in the nonattainment counties.

Trajectory Analysis

The amount of ground-level ozone measured at a particular site includes ozone and ozone emission precursors that were transported into the site's area at the time of measurement. A reasonably quick yet accurate technique for estimating a general surface "path" for an air mass parcel that ends up a specific point is called the "back trajectory". To calculate back trajectories for high ozone days, DNR staff used the most recent version of the HYSPLIT model developed by the U.S. National Oceanic and Atmospheric Administration (NOAA). Trajectories were started from the DNR ozone monitoring sites at Milwaukee-Bayside, Grafton, Manitowoc and Newport Beach.

A focus of this study was to track the path of an air parcel that impacted on each of the target sites at the hour when that site was measuring its peak daily 1-hour ozone value. Consequently, the time of the peak daily 1-hour ozone value for each site-day was the start hour for each back trajectory. DNR staff selected days when elevated 1-hour ozone concentrations occurred at the monitoring locations in question during the period 1991 through 1999. HYSPLIT input data was not available for all high ozone days in the period, limiting the analysis to a total of 20 days. HYSPLIT calculated each back trajectory for the 24 hours immediately prior to the time of the site's peak daily ozone occurrence.

In Wisconsin almost 100% of all high ozone site-days occur on days when the surface winds have a considerable southerly component. Consequently, every one of the back trajectories in this study has a strong southerly component. A review of the 24 hour back trajectories calculated for the four sites listed above during the 20 high ozone days indicate that there are two general surface air flow patterns contributing to elevated ozone concentrations in eastern Wisconsin:

A) On approximately half of the study days, the sites' back trajectories displayed a due southerly-to-southeasterly path. Good examples of this type of flow are those calculated 24-hour back trajectories for study sites on June 28, 1997 (Figures 4a & 4b).

B) On the remaining half of the study days, the sites' back trajectories indicated a strong southwesterly direction. This type of flow is exemplified in the 24-hour back trajectories for the study sites on June 29, 1997 (Figures 4c & 4d).

June 29 had much higher ozone concentrations (peak daily 1-hour ozone values at the 4 sites ranged between 108 – 154 ppb) than ozone concentrations on June 28 (peak daily 1-hour ozone values at the 4 sites ranged between 99 – 111 ppb).

The analysis indicates that ozone precursor emissions in the Secondary Control Region frequently contribute to high ozone concentrations in non-attainment counties in eastern Wisconsin. This analysis also provides independent support for the same conclusion that was reached through the zero-out runs described in this appendix.

HYSPLIT-Derived 24-hour Near Surface Back Trajectories
At Selected Wisconsin Ozone Sites

Trajectories calculated backward from time of site-peak daily 1-hour ozone occurrence

Figure 4a) Manitowoc, WI, 28 June 1997

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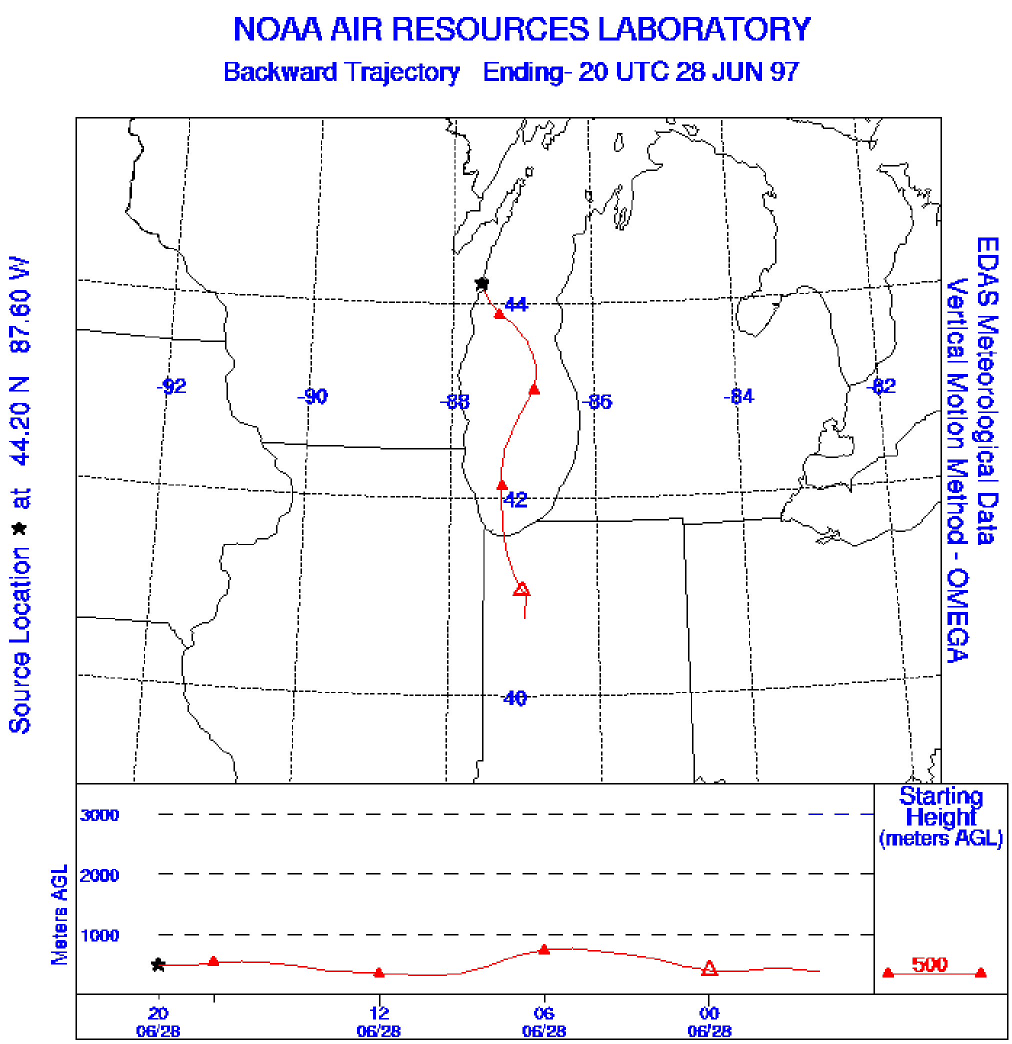

HYSPLIT-Derived 24-hour Near Surface Back Trajectories
At Selected Wisconsin Ozone Sites

Trajectories calculated backward from time of site-peak daily 1-hour ozone occurrence

Figure 4b) Newport, WI, 28 June 1997

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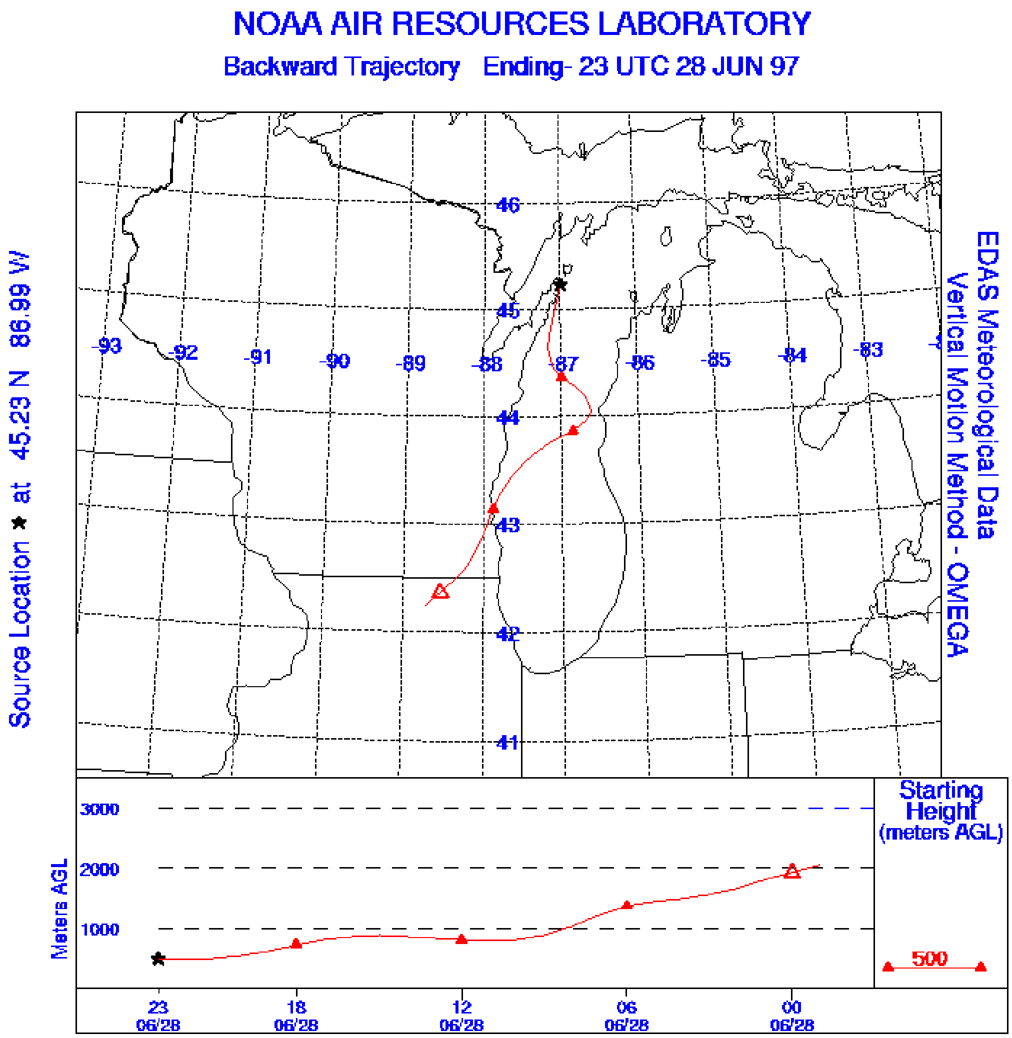

HYSPLIT-Derived 24-hour Near Surface Back Trajectories
At Selected Wisconsin Ozone Sites

Trajectories calculated backward from time of site-peak daily 1-hour ozone occurrence

Figure 4c) Manitowoc, WI, 29 June 1997

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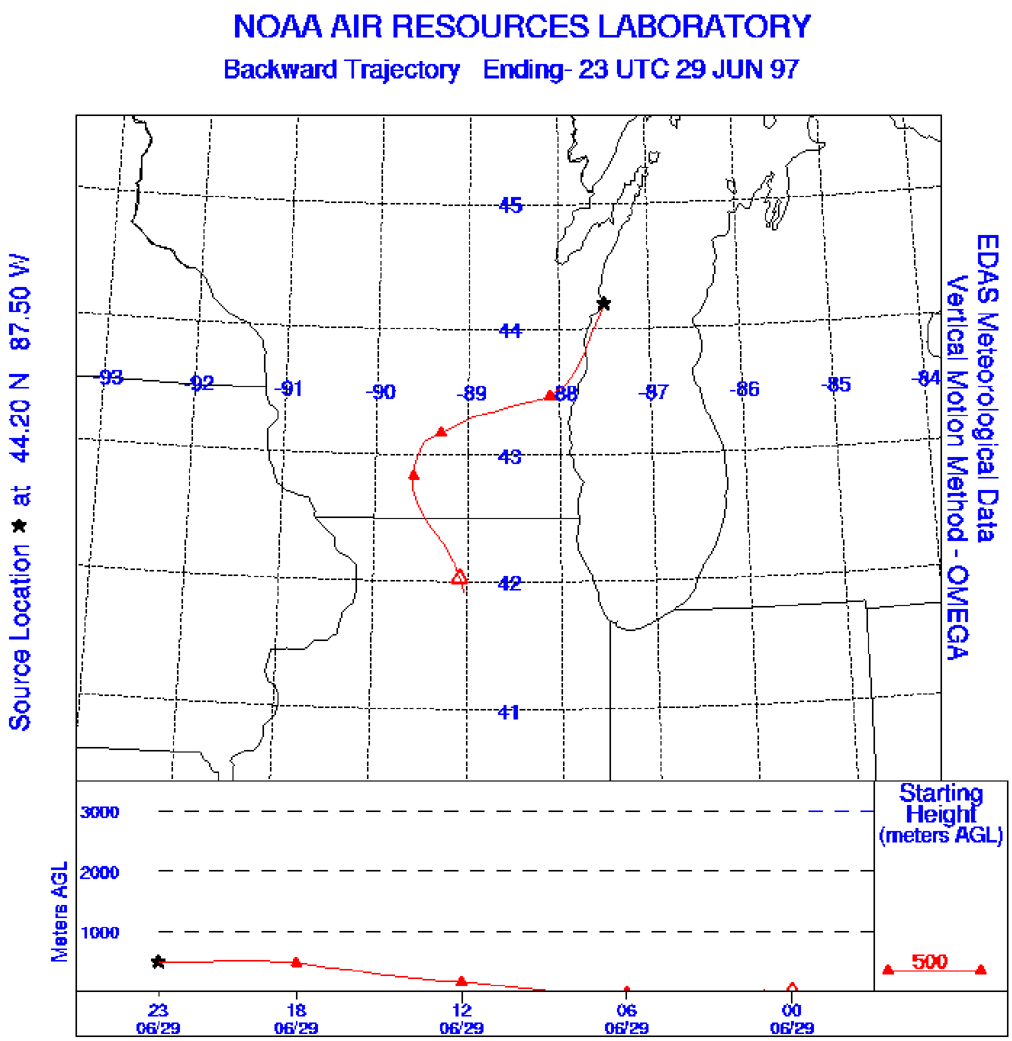

HYSPLIT-Derived 24-hour Near Surface Back Trajectories
At Selected Wisconsin Ozone Sites

Trajectories calculated backward from time of site-peak daily 1-hour ozone occurrence

Figure 4d) Newport, WI, 29 June 1997

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